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(54) Control system for shaft drive assembly

(57) Control of a shaft drive assembly is effected using a pair of micro control devices 1, 2 for controlling fuel metering by means of a metering valve 10 with a stepping motor 8, and for monitoring for shaft fracture and excessive rotational speed by means of sensors. The micro control devices 1, 2 can each carry out both control and monitoring functions. In normal mode the first micro control device 1 is the selected control device controlling the stepping motor 8 while the second micro control device 2 as the auxiliary control device monitors the permitted boundary data of the engine. The micro control devices are coupled in such a way that the control and monitoring functions can be switched over between the devices. In the event of a failure of one of the control devices, the other can take over both control and monitoring functions.

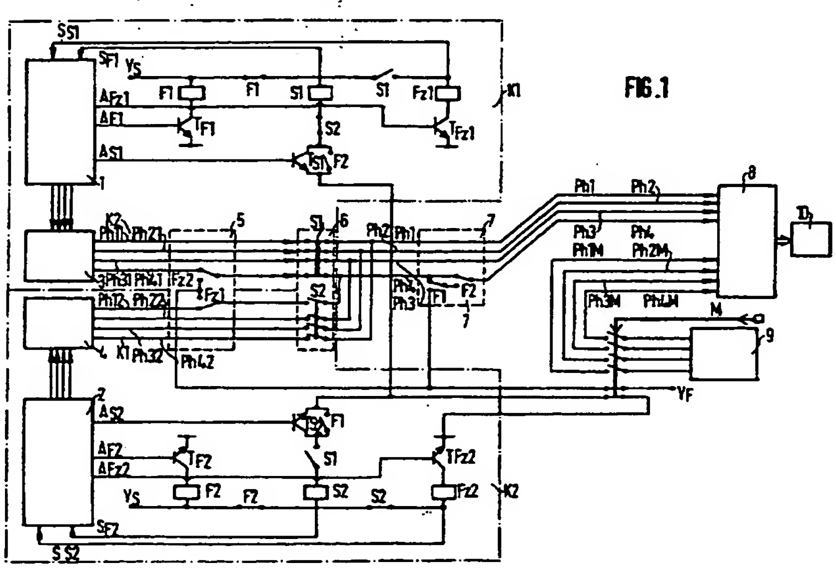

FIG.1

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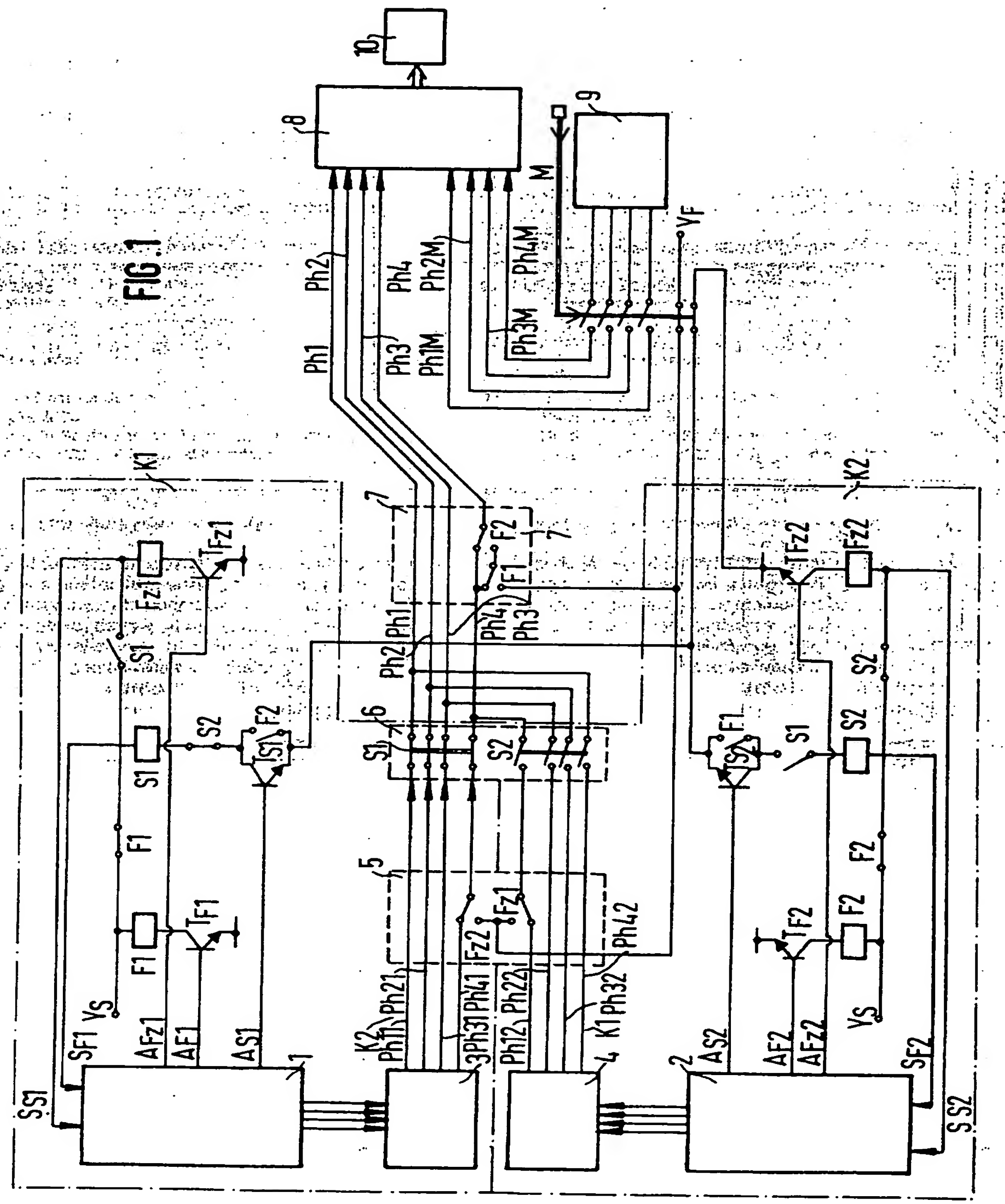

10
8
9
M
VF
Ph1
Ph2
Ph3
Ph4
Ph1M
Ph2M
Ph3M
Ph4M
K1
K2
Fz1
TFz1
Fz2
TFz2
S1
S2
F1
F2
TF1
TF2
VS
SF1
SF2
AFz1
AF1
AS1
AS2
AF2
AFz2
SS1
SS2
Ph11
Ph21
3Ph31
Ph41
Ph12
Ph22
Ph32
Ph42
1
2
3
4
5
6
7

FIG. 1

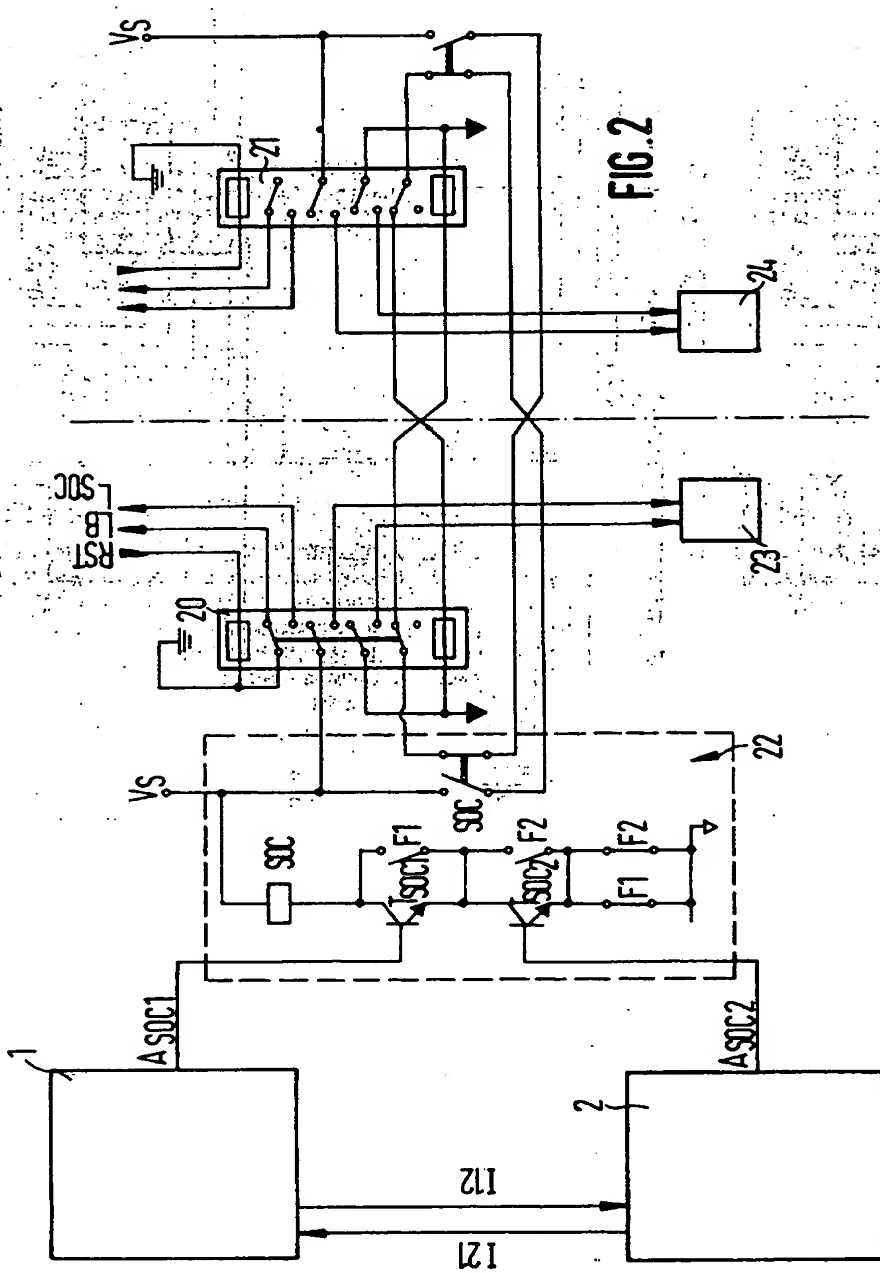
VS
21
24
FIG. 2
RST
LB
L SOC
20
23
22
VS
SOC
F1
F2
SOC1
SOC2
F1
F2
ASOC1
ASOC2
1
2
I12
I21

FIG. 2

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Shaft Drive Control

The invention relates to the control of a shaft drive assembly or engine with at least one micro control device such as a microprocessor for controlling the metering of fuel by means of a metering valve with a motor drive and/or channel cut-off logic, with monitoring of the engine for shaft fracture and excessive rotational speed by means of sensors.

Control systems of this type are known and operate typically with a large number of micro control devices. The known control devices use separate micro control devices for controlling the supply of fuel, monitoring the rotational speed of the engine or the shaft, and monitoring shaft fracture, as well as redundant micro control devices which, as supplementary or auxiliary control devices, double or triple the number of control devices required to reduce further the likelihood of a malfunction of a control device, which is about 10^{-6}.

Even if micro control devices of this type are already minimised in volume and weight, using them in quantities in an aircraft means a considerable space and weight requirement.

It has also not been conclusively proved that a plurality of auxiliary micro control devices increases reliability; on the contrary, tests show that unused non-active auxiliary devices often fail to provide service at the decisive moment. A solution in this case is regular alternating use of the auxiliary devices and the main devices. This has the disadvantage that the auxiliary devices are intermittently inactive and still represent an additional space requirement and additional weight.

A further disadvantage is that often the micro control devices with a monitoring function have the sole function of switching off the engine when

individual sensors indicate that limit values have been exceeded. This may lead to hasty and possibly catastrophic conclusions if the signals are incorrectly interpreted by a sensor.

It is the aim of the invention to provide a control system which manages with a reduced number of micro control devices, reduces the likelihood of incorrect functioning, can be used with great economy of space and weight, reduces the inactive phases of the micro control devices, and ensures an optimum control of shaft drive assemblies.

This aim is achieved with the control of a shaft drive assembly with at least one micro control device for controlling the metering of fuel by means of a metering valve with a motor drive and channel cut-off logic, with monitoring of the drive assembly for shaft fracture and/or excessive rotational speed by means of sensors, characterised in that a first and a second micro control device are joined together and locked with respect to each other in partial functions, the first micro control device as the selected control device controlling a stepping motor which operates the metering valve, and the second micro control device as the auxiliary control device monitoring the permitted boundary data of the drive assembly and is equipped with driver outputs which according to the fault (fault in the control devices, shaft fracture, excessive rotational speed) freeze the stepping motor position by means of a first logic switch, or trigger a fast cut-off by means of a transistor driver with a second logic switch connected downstream, or make possible a delayed cut-off by means of the second logic switch, the selected and the auxiliary control device being coupled together by means of the first and second logic switches and an additional direct data line in such a way that the functions can be alternately switched over

according to the setting of the first and second logic switches.

Two completely equivalent micro control devices are provided with completely equivalent functions but are not used simultaneously for the same function. On the contrary, a first micro control device controls the fuel consumption, for instance, whilst a second micro control device takes over the monitoring functions. Both devices are therefore constantly in use, i.e. one as the selected control device for fuel adjustment and the other as the auxiliary device for all the monitoring functions. In the case of total failure of one of the devices the other device can take over its functions. Provision is also advantageously made for the devices to switch over, i.e. to exchange functions. With this concept the likelihood of error is reduced to about 10^{-9}.

In addition a first and a second micro control device are preferably joined together and locked with respect to each other in partial functions. The first micro control device acting as the selected control device controls a stepping motor which operates the metering valve. The second micro control device, acting as the auxiliary control device, monitors the permitted boundary data of the engine and is equipped with driver outputs which freeze the stepping motor position by means of a first logic switch, or trigger a fast cut-off by means of a transistor driver with a second logic switch connected downstream, or in the case of excessive rotational speed make possible a delayed cut-off by means of the second logic switch. The selected and the auxiliary control device are coupled together by means of the first and second logic switches and an additional direct data line in such a way that the functions can be alternately switched over according to the position of the first and second logic

switches.

This control concept not only increases the reliability of control and monitoring but is also cost-effective and reduces the weight and space requirement in an aircraft.

The invention is also directed to a method of controlling a shaft drive assembly.

In a preferred embodiment of the invention the fast cut-off is triggered by the auxiliary control device and effected by the selected control device. This division of work has the advantage that monitoring for a fast cut-off can be carried out in the auxiliary control device at shorter intervals or cycles than the standard test for shaft fracture which is run in the selected micro control device, whose main task is fuel control and runs the shaft fracture test at longer intervals or cycles. However, if a shaft fracture of this kind is signalled by the faster auxiliary control device, then the standard cycle in the selected micro control device is interrupted by means of the data signal line and directly thereafter the shaft fracture test is carried out and on confirmation the fast cut-off of the fuel supply is brought about by the selected micro control device.

In a further preferred embodiment of the invention both micro control devices can carry out all the functions as individual devices during total failure of one control device, but the monitoring function for shaft rupture, in this case slowed down by the factor 3 to 10, is carried out by only one device. This has the advantage that with reduced reliability (likelihood of error about 10^{-6}) the engine is still fully functional with a single micro control device and all the monitoring and control functions are fulfilled. Moreover if the disadvantage of reduced reliability is permanently accepted then there can be a further

advantageous reduction in costs, space requirement and weight in omitting the second micro control device altogether.

In a preferred control process, the operation is carried out with a main cycle at a cycle time of 20 to 100 milliseconds and with say four sub-cycles with a control time t_R of 5 to 25 milliseconds. All the long-term functions can be processed in the main cycle and the short-term cycles can be accommodated in the sub-cycles. This control concept advantageously reduces the idle times and provides greater stability reserves for the control devices.

Shaft fracture monitoring belongs preferably in the short-term cycles, operating with cycle times of from $t_R/4$ to $t_R/10$. However, these short cycle times can only be achieved in short sequence by means of the solution of the invention if the control and monitoring functions are first of all carried out by two separately working micro control devices.

Cycle times preferably of $t_R/2$ to $2t_R$ are provided for monitoring overshoots of rotational speed, since this error requires no short-term reaction, as does a shaft fracture. Before reactions are triggered, i.e. before the selected micro control device is interrupted by means of the data signal line, in order then to block the supply of fuel, the operation is carried out for the sake of safety with 3-to-5 fold confirmation.

The different exertion of influence on the engine by co-operation of the micro control devices and the downstream logic switch is divided essentially into two cases. In one case the actual state of the fuel supply is frozen, i.e. it is neither increased nor decreased; in the other case the supply of fuel is abruptly blocked, In both cases, however, operators are given the possibility of operating the fuel supply manually.

Provision is always made for freezing when

statistical errors occur in the sensor technology or the microelectronics, or when temporarily switching over from one micro control device to the other. Complete blocking of the fuel supply is necessary with sudden shaft fracture or with sustained excessive rotational speed.

In another embodiment of the invention the stepping motor is operated via four phase supply lines with four phases which are controlled by means of a driver, and four-pole switching selectively by the first or the second micro control device when a selection signal is present at their outputs. This method of operation, known in principle, has the advantage in conjunction with the invention that a simple, cheap and easily installable solution can be found for the freezing operation. Freezing of the position of the stepping motor, and hence of the position of the metering valve, is preferably effected by applying a stop voltage of 12 to 48 V at one of the phase supply lines of the stepping motor by means of relay contacts in the first logic switch.

With this logic switch, which has to be located in front of the switch for change-over of the functions of the two control devices so that both one and the other can exert the same influence on the engine when the functions are swapped, an influence on the engine is not produced in every case when a faulty operation of the micro control devices themselves occurs. Therefore an error signal at one of the outputs of the micro control devices preferably causes freezing of the position of the stepping motor and hence the position of the metering valve by applying a stop voltage of 12 to 48 V at one of the phase supply lines of the stepping motor by means of relay contacts of a third logic switch, this third logic switch being arranged after the switch-over device.

In the case of a fast cut-off upon shaft fracture the non-selected second micro control device as the auxiliary control device preferably interrupts the selected first micro control device in its main cycle by means of a signal line, and causes it to switch over to shaft fracture mode. After independent testing by the first micro control device and confirmation of the shaft fracture, an output signal is generated at the first micro control device and by means of the second logic switch switches off the engine by blocking the fuel metering valve.

These solutions for controlling shaft power drive assemblies ensure on the one hand that there is no inactive redundancy in the aircraft and on the other hand safety and reliability are substantially greater than with single-channel control.

An embodiment of the invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 shows a partial circuit diagram for a preferred embodiment of the invention with a control device for switching over the engine control and for freezing the supply of fuel; and

Fig. 2 shows a partial circuit diagram for a preferred embodiment of the invention with a control device for blocking the supply of fuel in the case of shaft fracture, excessive rotational speed or other serious engine defects.

Fig. 1 shows a partial circuit diagram for a preferred embodiment of the invention with a control device for switching over the engine control and for freezing the supply of fuel to a shaft drive assembly, having at least one micro control device or processor 1

for controlling the metering of fuel by means of a metering valve 10, controlled by a motor drive 8 via several signal-selection logic blocks 4, 5, 6, 7, and 22 in Fig. 2, such as a channel switch-over logic 6, two freezing logic circuits 5, 7 and a channel switch-off logic 22, as indicated in Fig. 2, with monitoring of the engine for shaft fracture and excessive rotational speed by means of sensors.

This embodiment makes use of two micro control devices 1 and 2, with which the interfaces for a stepping motor 8 for controlling fuel supply and for the fast cut-off of a blocking valve, such as for instance an emergency shutdown valve 23, shown in Fig. 2, for the supply of fuel are already installed. The outputs of the micro control devices 1 and 2, namely A_{Fz1} or A_{Fz2} for freezing the fuel supply, A_{F1} or A_{F2} for freezing the fuel supply when a malfunction of the sensor technology or of the micro control devices is identified in the case of an error in both channels, A_{S1} or A_{S2} for the selection of one of the micro control devices as the regulator of the fuel supply, and A_{SOC1} or A_{SOC2} in Fig. 2 for a fast cut-off of the fuel supply in the case of shaft fracture or excessive rotational speed, are conveyed by means of power end stages T_{Fz1} and T_{Fz2}, T_{F1} and T_{F2}, T_{S1} and T_{S2}, and T_{SOC1} and T_{SOC2} respectively in Fig. 2 into the signal-selection-logic 5, 6, 7 as shown in Fig.1 and 22 in Fig. 2. Accordingly, a first and a second micro control device 1, 2 are coupled together and locked in partial functions with respect to each other.

The first micro control device 1 as the selected control device controls, for instance, a stepping motor 8 which drives the metering valve 10. The selection of the micro control device 1 is effected via the switch-over block with the selection logic 6 by the relay S1 which is assigned to an output A_{S1} of the micro control

device 1 or by the relay S2 which is assigned to an output A_{S2} of the micro control device 2. The relays S1 and S2 are locked with respect to each other and coupled in such a way that the following logic is reliably achieved for the channels K1 and K2:

1. channel K1 selected AND channel K2 off;
2. channel K1 off AND channel K2 selected;
3. channel K1 off AND channel K2 off:

Case 3 is only activated when both micro control systems have a total failure. In this case both outputs A_{F1} or A_{F2} are set at error potential and the relays F1 and F2 drop away so that the associated contacts F_1 or F_2 in the logic mode 7 set one of the control phases Ph1-4 of the stepping motor 8 to a fixed potential V_F and hence freeze the position of the stepping motor 8, the position of the metering valve 10 and the amount of fuel supplied, i.e. the fuel supply is neither increased nor decreased.

For controlling the stepping motor 8 the channels K1 and K2 have in this instance four phases Ph_1, Ph_2, Ph_3, Ph_4 on the supply lines to the stepping motor, one of the phases being channelled through a first selection or relay logic 5 for freezing the current fuel supply. This logic 5 ensures that in the case of an error not identified by the selected channel, the non-selected channel may prevent a critical error function for the shaft power drive assembly. Freezing is effected by one of the four phases here Ph_4, being set to the already mentioned fixed potential V_F, which in this example is between 12 and 48 V, with 28V being selected here.

Consequently the second micro control device 2, which in this case is connected as the auxiliary control device, can monitor the permitted boundary data of the engine and for this purpose is equipped with the driver outputs A_{S2}, A_{F2}, A_{F22} shown in Fig.1 and A_{SOC2} in

Fig. 2.

For the sake of completeness, a manual emergency control device 9, already known for devices of this kind, has been integrated into the preferred exemplary embodiment of Fig. 1, and makes it possible for the operator to switch over to manual operation. At the same time this is an example of how the control device of the invention can be integrated to advantage into existing installation and regulation concepts.

Fig. 2 shows a partial circuit diagram of a preferred embodiment of the invention, with a control device for blocking the supply of fuel in the case of shaft fracture, excessive rotational speed or other serious engine defects. For this purpose an emergency shutdown valve 23 for the fuel is actuated. The control for the emergency shutdown valve 23 is designed so that the micro control device not selected for control of the stepping motor monitors the rotational speeds measured by the sensors for shaft fracture and excessive rotational speed in a short cycle of about 0.5 to about 6 ms, in this example 2 ms. If this type of faulty functioning of the engine is identified, this second micro control device sets its output A_{SOC2} and by means of the data signal line I_{21} causes an interruption in the running of the control procedure for controlling the fuel supply in the first micro control device. This device in turn, somewhat delayed (about 0.5 ms), also carries out this test for shaft fracture, for instance, and accordingly controls its own output A_{SOC1}. When both micro control devices 1 and 2 have set their outputs A_{SOC1} and A_{SOC2} the emergency cut-off is activated by means of the relay logic 22. Mistaken emergency cut-off of the engine due to an electrical malfunction is therefore extremely unlikely.

If one of the two micro control devices 1 or 2 fails, the contact of the associated relay F1 or F2 is

closed and the entire authority via the emergency shutdown valve 23 is transmitted to the error-free micro control device 2 or 1.

In the case where both micro control devices 1 and 2 fail, both F-relays are closed (fall away) and the emergency cut-off relay SOC can no longer be controlled. The likelihood of the coincidence of a double error in the device and a fracture of the shaft is practically zero.

The embodiment according to Fig. 2 assumes two engines with shafts independent of each other. The dot-dash line is intended to indicate the interface with the second engine with a second emergency shutdown valve 24. By controlling the emergency cut-off relay SOC first of all the emergency cut-off of the second engine is locked and then the emergency cut-off of the first engine is triggered. Safety and reliability are therefore increased because the following safety requirements are guaranteed:

1. When one engine is switched off, the second engine can no longer be switched off;
2. With simultaneous triggering of the switch-off both engines, neither of them may be switched off.

The downstream bistable relay 20 means that once started an emergency switch-off can only be reset by the flight personnel.

Control of the two micro control devices is effected in two different modes. The first micro control device 1 selected for control of the engine runs the control programme which is responsible for control of the stepping motor 8, in one mode at a cycle or period of about 20 to 100 milliseconds, in this example 50 ms. The second non-selected micro control device 2, used for monitoring the characteristic data of the engine, runs the control of the monitoring, for

instance for shaft fracture and excessive rotational speed, in one mode at a cycle or period of 0.5 to 6 ms. In addition, monitoring of the engine operating point is effected as a background.

On identifying the shaft fracture the output A_{SOC2} is immediately set and at the same time the first micro control device is interrupted by means of the data signal line I_{21} in the running of the intended fuel supply regulation.

When the engine has reached an impermissible operating point, such as excessive rotational speed, then first of all in this example the output A_{F22} of the second micro control device is set. In the case of excessive rotational speed, if excessive rotational speed still applies a few milliseconds later, and this has been confirmed 3-to-6-fold, the output A_{SOC2} with associated emergency switch-off relay SOC is set.

This division of control in accordance with the invention means that it is possible, with relatively low expenditure on hardware, both to control the engine with short idling time and to carry out effective monitoring of shaft fracture and excessive rotational speed.

Claims

1. A control system for a shaft drive assembly, including:

a pair of micro control devices (1,2) for controlling the metering of fuel; and

means for monitoring the drive assembly for shaft fracture and/or excessive rotational speed;

in which one of the micro control devices (1) acts as the selected control device controlling the fuel metering, and the other micro control device (2) acts as an auxiliary control device monitoring the critical data of the drive assembly and is equipped with outputs (A_{S2}, A_{F2}, A_{Fz2}) for freezing the fuel setting for one kind of fault or triggering a cut-off for another, more serious, kind of fault, the selected and the auxiliary control device (1, 2) being coupled together in such a way that the functions can be alternately switched over between the two control devices.

2. A control system according to claim 1 and further including first and second logic switches (5, 22), in which the first switch (5) mediates the output for freezing the fuel setting and, by means of a transistor driver (T_{SOC1}, T_{SOC2}), the second logic switch (22) triggers the fast cut-off and makes possible a delayed cut-off by means of the second logic switch (22), and in which the functions are switched over according to the setting of the first and second logic switches (5, 22).

3. A control system according to claim 1 or 2, in which the control devices are coupled together by means of the first and second logic switches (5,22) and an additional direct data line (I_{21}, I_{12}).

4. A control system according to any preceding claim, in which the fast cut-off is triggered by the auxiliary control device and is effected by the selected control device.

5. A control system according to any preceding claim, in which both micro control devices (1, 2) can fulfil all the functions as individual devices when there is a total failure of one control device, but the monitoring function for shaft fracture in this case is carried out slowed down by a factor of 3 to 10.

6. A control system according to any preceding claim, in which the control is effected with a main cycle at a period of 20 to 100 milliseconds and with 4 sub-cycles at a period t_R of 5 to 25 milliseconds.

7. A control system according to claim 6, in which the shaft fracture monitoring is carried out in a sub-cycle of period $t_R/4$ to $t_R/10$.

8. A control system according to claim 6 or 7, in which the rotational speed is monitored within a sub-cycle of period $t_R/2$ to $2t_R$ with 3-to-5 fold confirmation.

9. A control system according to any preceding claim, in which the control device controls the fuel by means of a metering valve with a stepping motor drive and by means of channel cut-off logic.

10. A control system according to claim 9, in which the stepping motor (8) is operated by means of four-phase supply lines (P_{h1}, P_{h2}, P_{h3}, P_{h4}) which are controlled by means of a driver (3, 4) and four-pole switching (6) selectively by the first or second micro control device when a selection signal is present at their outputs (A_{S1}, A_{S2}).

11. A control system according to claim 10, in which freezing of the position of the stepping motor and hence of the position of the metering valve is effected by applying a stop voltage of 12 to 48 V at one of the phase supply lines (P_{h1}, P_{h2}, P_{h3}, P_{h4}) of the stepping motor (8) by means of relay contacts (F_{z1}, F_{z2}) in the first logic switch (5).

12. A control system according to claim 10 or 11, in which an error signal at one of the outputs (A_{F1}, A_{F2}) of the micro control devices (1, 2) causes freezing of the position of the stepping motor and hence the position of the metering valve by applying a stop voltage of 12 to 48 V at one of the phase supply lines (P_{h1}, P_{h2}; P_{h3}, P_{h4}) of the stepping motor (8) by means of relay contacts (F_1, F_2) in a third logic switch (7).

13. A control system according to any preceding claim, in which in the case of a fast cut-off upon shaft fracture the non-selected second micro control device (2), acting as an auxiliary control device, interrupts the selected first micro control device in its main cycle by means of a signal line I_{21}, and switches it over to shaft fracture test mode, and after independent testing by the first micro control device (1) and confirmation, an output signal (A_{SOC1}) at the first micro control device (1), via the second logic switch (22), switches off the drive assembly by blocking the fuel metering valve.

14. A control system according to any preceding claim, in which the first and second micro control devices (1,2) are joined together and locked with respect to each other in partial functions.

15. A system or method for controlling a shaft drive by means of two equivalent micro control devices, one for carrying out the routine control of the fuel metering and one for the monitoring of faults, the latter applying suitable override functions when certain faults are detected, in which the two micro control devices are adapted to be interchangeable so that the control function can be performed by the former monitoring device and vice versa.

16. A system or method for controlling a shaft drive by means of two equivalent micro control devices, one for carrying out the routine control of the fuel

metering and one for the monitoring of faults, the latter applying suitable override functions when certain faults are detected, in which both micro control devices are capable of performing both the control and the monitoring so that in the case of failure of one device the other can maintain control and monitoring intact.

17. An engine control system substantially as described herein with reference to the accompanying drawings.

18. A turbine engine including a control system as claimed in any preceding claim.